

OUTGOING LONGWAVE RADIATION OF THE TIBETAN PLATEAU

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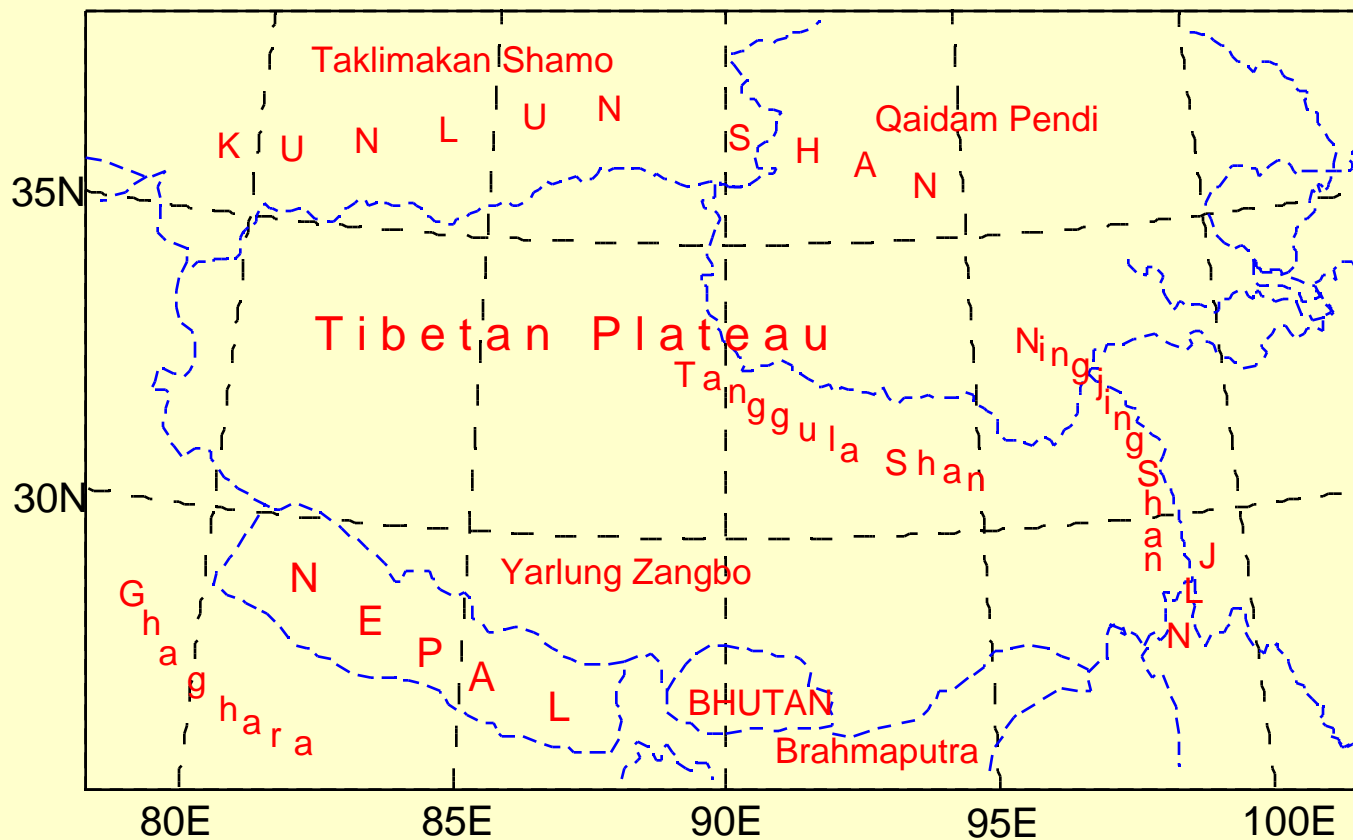
(Hampton University/NASA Langley Research Center)

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SATELLITE DATA

- Geostationary Meteorological Satellite (GMS5) positions over 140°E and composes of four channels:
 - 11.5-12.5 μm
 - 10.5-11.5 μm
 - 6.5-7.0 μm
 - 0.5-0.75 μm
- The data we used in this paper is from August 1996 to July 1998 for the area of the Tibetan Plateau(78°E~102°E, 26°N~38°N)

The Tibetan Plateau



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Retrieving OLR from the GMS5 Satellite

To retrieve OLR from the GMS5 observed radiances of split-window channels (10.5-11.5 and 11.5-12.5 μm) and water vapor (6.5-7.0 μm) channel for the Tibetan Plateau, the DISORT model is applied to simulate the radiances of the three channels. Radiosonde data of five stations of the Tibetan Plateau are input (no less than 200 sonde profiles for each station) to the DISORT model, and both clear and cloudy conditions are considered.

To accurately simulate radiation fluxes F and multiangle radiances $L(\theta)$ for the split-window channels and the water vapor channel (labeled as channels 1, 2, and 3, respectively), 16 stream is adopted in the DISORT model; for OLR simulation, 4 stream is enough.

Retrieving OLR from the GMS5 Satellite (cont'd)

Based on the model simulations, the narrow band radiances are translated into narrow band fluxes:

$$F_{IR1} = a1(\theta)L_{IR1}(\theta) + b1(\theta)$$

$$F_{IR2} = a2(\theta)L_{IR2}(\theta) + b2(\theta)$$

$$F_{wv} = aw(\theta)L_{wv}(\theta) + bw(\theta)$$

F_{IR1} , F_{IR2} , F_{wv} are radiation fluxes for channel 1, 2, and 3 derived from model calculations; L_{IR1} , L_{IR2} , and L_{wv} are correspondent radiances, which can be obtained from GMS5 observations; and $a1$, $b1$, $a2$, $b2$, aw , and bw are regression coefficients.

Retrieving OLR from the GMS5 Satellite (cont'd)

The dependence of radiance on zenith angle can be expressed in terms of an empirical limb-darkening function

$$L(0) = L(\theta) + [\alpha_1 + \alpha_2 L(\theta)](\sec\theta - 1) + [\beta_1 + \beta_2 L(\theta)](\sec\theta - 1)^2$$

where α_i and β_i are regression coefficients. Then F can be expressed as:

$$\begin{aligned} F_{IR1} &= a1(0)L_{IR1}(0) + b1(0) \\ &= b1(0) + a1(0)[\alpha_1(\sec\theta - 1) \\ &\quad + \beta_1(\sec\theta - 1)^2] + a1(0)[1 + \alpha_2(\sec\theta - 1) + \beta_2(\sec\theta - 1)^2]L_{IR1}(\theta) \end{aligned}$$

Retrieving OLR from the GMS5 Satellite (cont'd)

From the two equations above, coefficients a_i and b_i can be derived:

$$\begin{aligned} a_1(\theta) &= a_1(0)[1 + \alpha_2(\sec\theta - 1) + \beta_2(\sec\theta - 1)^2] \\ &= k_{1_1} + k_{1_2}(\sec\theta - 1) + k_{1_3}(\sec\theta - 1)^2, \end{aligned}$$

$$\begin{aligned} b_1(\theta) &= b_1(0) + a_1(0)[\alpha_1(\sec\theta - 1) + \beta_1(\sec\theta - 1)^2] \\ &= k_{1_4} + k_{1_5}(\sec\theta - 1) + k_{1_6}(\sec\theta - 1)^2. \end{aligned}$$

Coefficients k_{1_i} , k_{2_i} , and k_{3_i} are obtained from regression analysis of the DISORT model outputs for each radiosonde station. The averaged regression results of five radiosonde stations are listed below.

k_{1_i}	k_{2_i}	k_{3_i}
3.167	1.881	1.553
-0.064	0.392	0.610
-0.005	-0.051	-0.082
1.232	1.227	1.296
0.633	0.644	0.508
-0.078	-0.082	-0.067

Retrieving OLR from the GMS5 Satellite (cont'd)

The broad band OLR can then be determined from narrow band F_{IR1} , F_{IR2} , and F_{wv} with a third-order polynomial:

$$\text{OLR} = \xi_0 + \sum_{i=1}^3 \xi_i F_{IR1}^i + \sum_{i=1}^3 \zeta_i F_{IR2}^i + \sum_{i=1}^3 \psi_i F_{wv}^i.$$

The regression coefficients ξ_i , ζ_i , and ψ_i are then averaged for the five radionsonde stations and the results are listed below:

Channel 1	Channel 2	Channel 3
$\xi_0=66.017$		
$\xi_1= 4.367$	$\zeta_1= 0.271$	$\psi_1=36.551$
$\xi_2= 0.112$	$\zeta_2= 0.169$	$\psi_2= 1.459$
$\xi_3=-0.005$	$\zeta_3=-0.005$	$\psi_3=-2.027$

Correction

The Tibetan Plateau is nearly out of the effective observational range of the GMS5 satellite (80°E~160°W, 60°N~60°S), so the accuracy of the OLR for the Tibetan Plateau derived from the GMS5 may be affected. To correct the error induced by the location of the Tibetan Plateau, TOVS on board the polar-orbiting NOAA 12 satellite is employed. The passing times for NOAA 12 are around 0000 and 1200 UT, so we choose GMS5 satellite data according to the passing times of the NOAA 12 to obtain simultaneous OLRs for both satellites (the passing time differences between GMS5 and NOAA 12 are no more than 30 min)

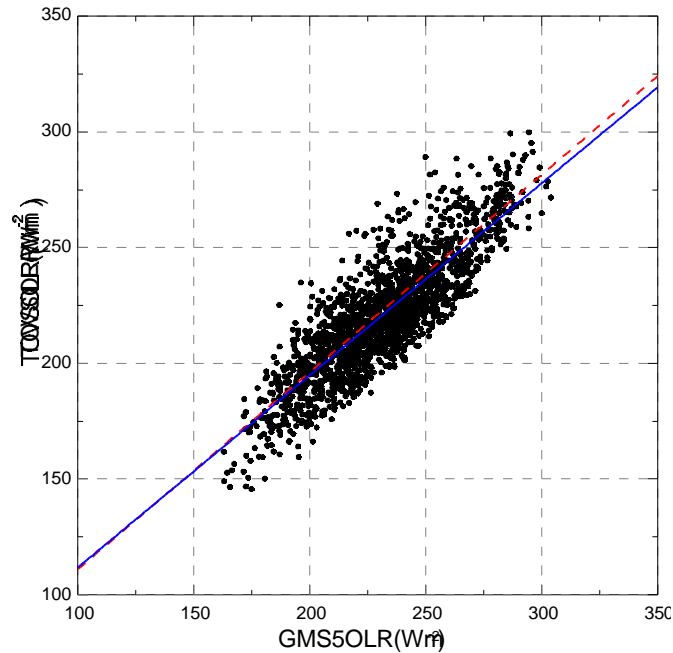
The resultant regression formulas between OLR_T and OLR_G for 0000 and 1200 UT are

$$OLR_T = 28.8 + 0.8298 OLR_G$$

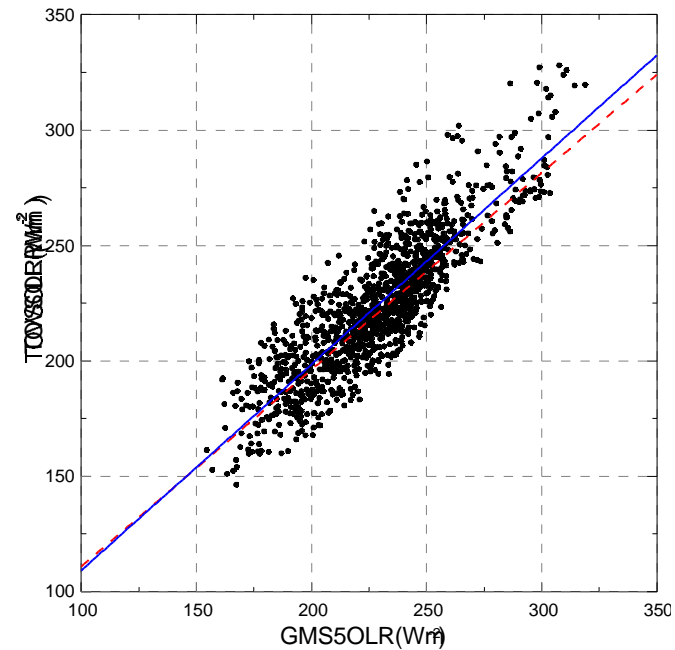
$$OLR_T = 20.0 + 0.8926 OLR_G$$

The total samples used in the above regressions are 1970 and 1211, respectively. The correlation coefficients are 0.8512 and 0.8639, which are much larger than for 1% significant level.

Correction (cont'd)



(a)



(b)

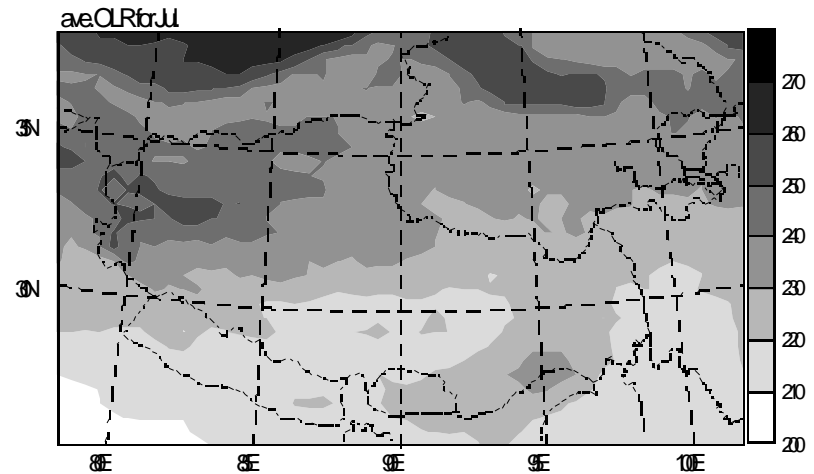
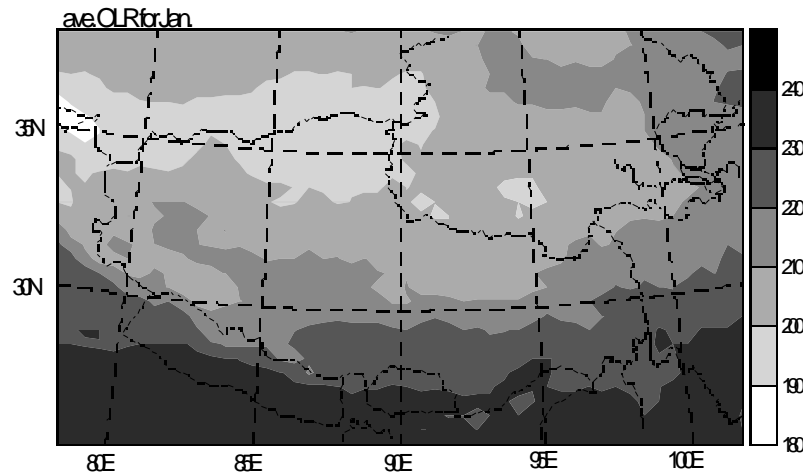
Relationship between OLR_T and OLR_G (a) 0000 UT and (b) 1200 UT.
(Solid lines are fitting results for 0000 UT (Figure 2a) and 1200 UT (Figure 2b)
and dashed line is regression result considering both hours.)

It is reasonable to assume that the correction does not depend on time, and the samples of 0000 and 1200 UT are considered together to give out the regression equation which will be used for other times of the day:

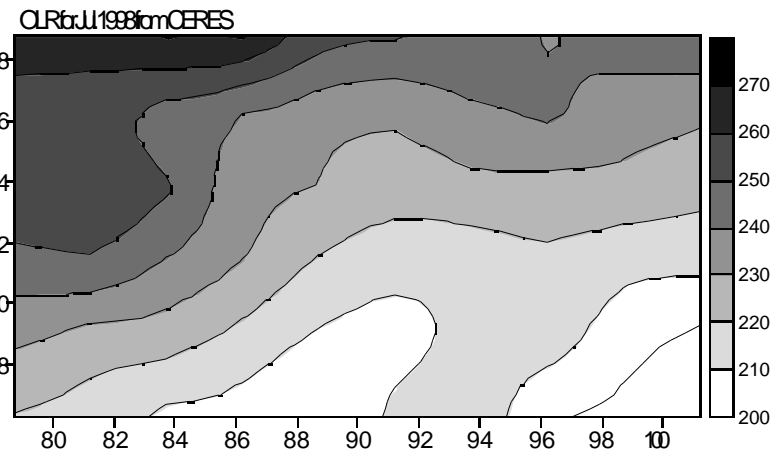
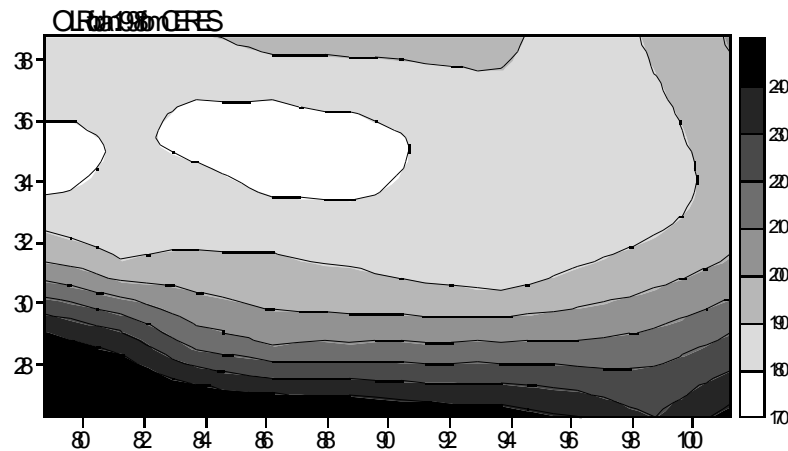
$$OLR_T = 25.7 + 0.8524 OLR_G.$$

The correlation coefficient is 0.8510.

Monthly Mean OLR Distribution Over Tibetan Plateau

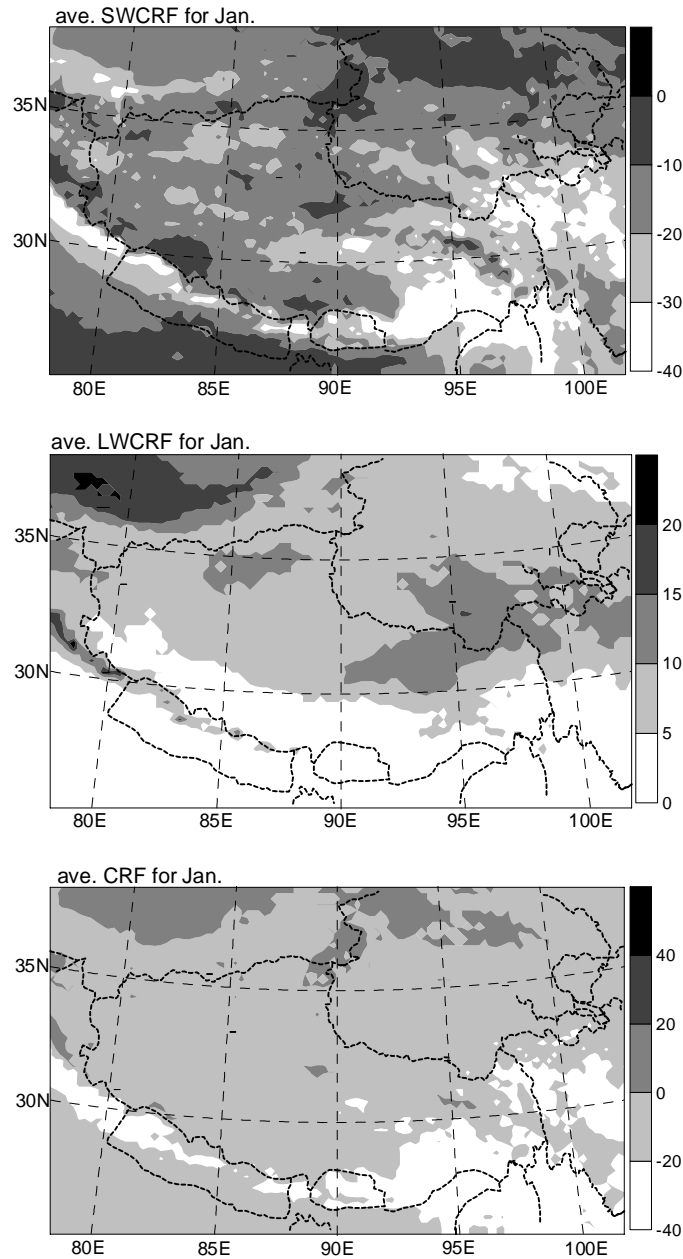


Monthly mean OLR distributions over the Tibetan Plateau for January and July from GMS5.



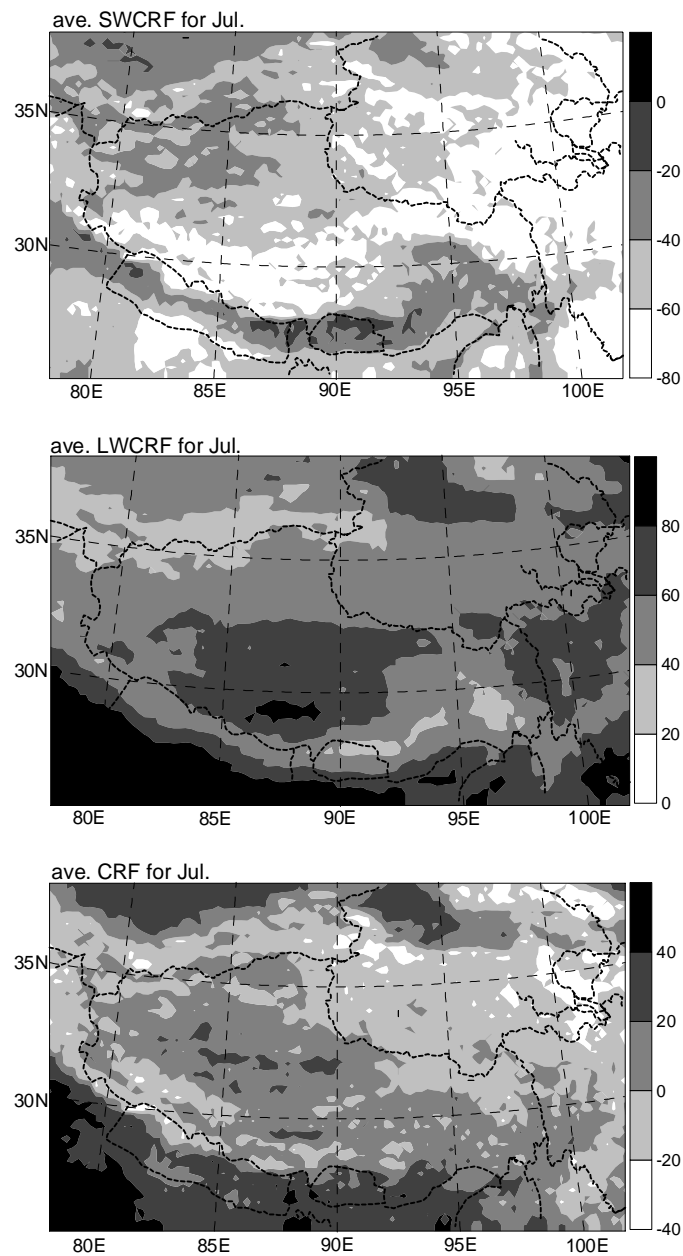
OLR distributions over the Tibetan Plateau from CERES results for January and July.

Cloud Radiative Forcing of January



Monthly mean shortwave cloud radiative forcing (SWCRF), longwave CRF (LWCRF), and CRF over the Tibetan Plateau for January.

Cloud Radiative Forcing of July



Monthly mean SWCRF, LWCRF, and CRF
over the Tibetan Plateau for July

Annual Variations of SWCRF, LWCRF and CRF

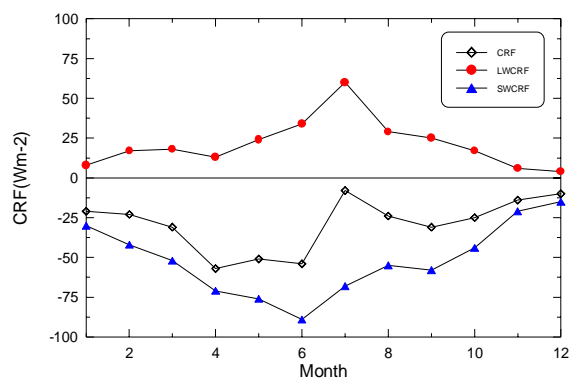


Figure 9. Annual variations of SWCRF, LWCRF and CRF for Changdu

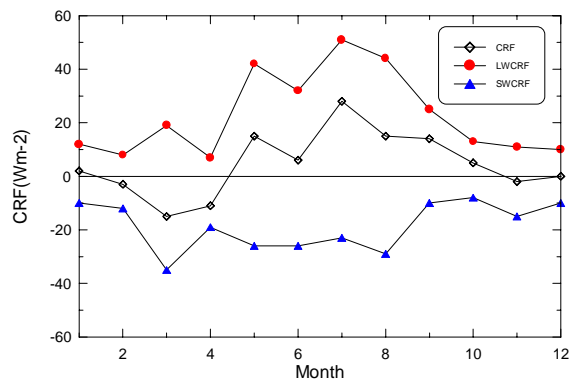


Figure 10. Annual variations of SWCRF, LWCRF and CRF for Taklimakan Shamo (Desert)

Summary

- The correlation coefficient between GMS5 OLR and TOVS OLR is 0.8510. The correction is nearly time independent.
- During the winter season the OLR distribution exhibits low values over the Tibetan Plateau but high values for areas off the Tibetan Plateau. During the summer season the OLR of the southern part is smaller than that of the northern part, and they are in good accordance with the CERES results.
- The annual variations of OLR for the southern part of the Tibetan Plateau and the northern part of the India Island have a bipeak mode with maximums appearing in May and October and the minimum appearing in March. The annual variations of OLR for the northern part of the Tibetan Plateau have a single-peak mode with the maximum value appearing in July.

Summary

- The diurnal variations of OLR are affected by diurnal cycles of cloud quantity and surface temperature. The relief of the Tibetan Plateau is very high, and the radiative heating is intense after sunrise, so the OLR is significantly influenced by the surface and reaches a maximum soon after sunrise. However, the minimum OLR differs by month.
- The diurnal variations of OLR for areas around the Tibetan Plateau are different from those of the Tibetan Plateau.
- CRF over the Tibetan Plateau is negative most of the time, which means the CRF is dominated by cooling effects and the distribution pattern is mainly determined by the SWCRF component. While the CRF to the south and to the north of the Tibetan Plateau are different, CRF shows obvious annual variations that demonstrate heating effects in the summer-autumn season and cooling effects in the winter-spring season